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A Factor and Structural Equation analysis of the Enterprise Systems Success Measurement Model

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ABSTRACT

Despite the optimistic motives, many Enterprise Systems projects have reported nil or detrimental impacts. Understanding the dimensionality of ES success, the theoretical considerations and the development of a standardized instrument to gauge the level of success are critical in ES evaluations. In an attempt to increase the validity of conclusions of ES assessment studies, survey instrument design should follow a rigorous and scientific procedure. The study reported in this research completes the research cycle for developing a standardized instrument by (1) completing an exploratory study that develop hypothesized measurement model and a survey via the analysis of empirical data from a referent population and (2) a subsequent confirmatory study to test the validity and the reliability of the hypothesized measurement model against new empirical data.

Key words

Enterprise System, IS research Methodologies, Multiple Criteria Evaluation

INTRODUCTION

Organisations make large investments in Enterprise Systems (ES) expecting positive impacts to the organisation and its functions. Yet, there exists much controversy surrounding the ‘potential’ impacts of these systems with some studies reporting positive impacts of ES in organizations, while others have shown nil or detrimental impacts. These conflicting results may be attributable to (1) incomplete or inappropriate measures of success, (2) lack of theoretical grounding of causal and process models of IS success, (3) myopic focus on financial performance indicators, (4) data collection approach (e.g., asking the wrong people) or weaknesses in (5) survey instruments employed (e.g., constructs lacking in validity). This paper focuses specifically on the weaknesses in instrument design and attempts to establish a standardized instrument to measure ES success¹. The importance of developing standardized instruments for measuring ES success is an important contribution to both academia and to the practice. In order to develop a standardized instrument Mackenzie and House 1979 and McGrath 1979 propose ‘the research cycle’ which entails two main phases: (1) *exploratory phase* to develop hypothesized measurement models and (2) *confirmatory phase* to test hypothesized measurement models against new data gathered. The ES success measurement model presented herein was derived by completing the *exploratory* phase of the research cycle (Gable, Sedera, Chan 2003; Sedera, Gable, Chan 2003a). This paper completes the instrument development research cycle by analysing new data to test the validity of the exploratory findings using a confirmatory analysis².

This paper begins with a discussion on the research design. Then a synopsis of the exploratory phase³ is provided, followed by a detail analysis of the confirmatory phase. The data analysis of the confirmatory survey was completed with confirmatory factor analysis with LISREL and was supplemented with validity and reliability measures.

¹ See Gable, Sedera, Chan (2003) for a detailed discussion of other weaknesses

² A confirmatory analysis is needed to facilitate a more rigorous, standardized survey instrument with validated items (Bollen 1989; Joreskog and Sorbom 2001).

³ For exploratory study results please refer Gable, Sedera, Chan 2003; Sedera, Gable, Chan 2003a; Sedera, Gable, Chan 2003b; Sedera, Gable, Chan 2003c; Sedera, Gable, Chan 2003d

THE RESEARCH DESIGN

Figure 1 depicts the two-phased research design followed in this study. Three surveys (inventory, weights and confirmatory) were employed to complete the research cycle and information was gathered from six hundred respondents in total. Table 1 summarizes details of the three surveys. Two surveys were conducted in the exploratory phase: (1) inventory survey and (2) weights survey. This dual survey approach goes beyond the recommended single survey approach of Mackenzie and House 1979 and McGrath 1979. The purpose of the *inventory survey* was to identify the salient success dimension and measures, which are subsequently the focus of a *weights survey*, for evaluating a priori model validity. The a priori ES success model was empirically tested with survey data gathered from 27 Australian State Government Agencies that had implemented SAP R/3 in the late 1990s. The inventory and weights surveys yielded 137 and 310 responses respectively. In addition to the main data collection survey rounds, a series of expert workshops with industry and academic experts was conducted. The final ES success model from the exploratory phase employs 27 measures of ES success arranged under four dimensions: information quality, system quality,

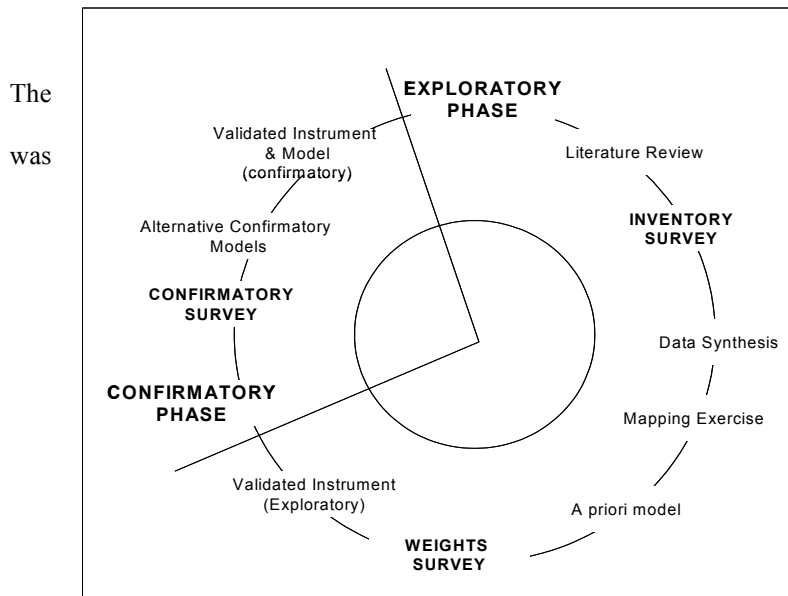


Figure 1: Research design

individual impact, and organizational impact. confirmatory survey was conducted with these validated survey items and constructs. New data gathered from 153 respondents from a large University that had implemented ORACLE Enterprise System. These responses are being used to confirm the ES success survey instrument reported herein.

Research Phase	Purpose	Organization	ES	#
Exploratory				
Inventory Survey	To identify the salient success dimensions and measures	Australian Public Sector	SAP R/3	137
Weights Survey	To test the a priori model derived from the Inventory Survey	Australian Public Sector	SAP R/3	310
Confirmatory				
Confirmatory Survey	To validate the instrument and ES success model	Higher Education	Oracle	153

Table 1: Details of the three surveys

EXPLORATORY PHASE: THE INVENTORY SURVEY

The main purpose of the initial exploratory inventory survey was to identify a salient set of ES success dimensions to include in the *a priori* ES success measurement model. In September 2001, the exploratory survey was conducted to inventory impacts of the SAP R/3 system, as perceived by staff at all levels of 27 Government agencies in Australia. A total of 137 responses were received, citing a total of 485 impacts (Sedera, Gable, Palmer 2002). The citations of the inventory survey were then synthesized into a useful, meaningful, and coherent classification of success dimensions and measures. The objectives of this exercise were to yield a framework that is (1) simple and generalizable beyond the current study, while also being (2) intuitive to the study respondents. An attempt was made to map the first-round survey 'citations' into both the Delone and McLean IS success model (1992: 2002: 2003) – supplemented with the Myers, Kappelman, Prybutok (1997) IS assessment selection model, as well as into the Shang and Seddon ERP benefits framework (2000). The synthesis process identified the constructs and underlying measures of the Delone and McLean (1992) model and the associated measures from

Myers et al (1997), as the most suitable taxonomy of ES success⁴ (Gable, Sedera, Chan 2003; Sedera, Rosemann, Gable 2001). The Delone and McLean success dimensions and measures were then adapted to the context of ES⁵.

Having started with the Delone and McLean constructs and measures (supplemented by Myers et al.), and having adapted their framework through review of the literature, the inventory survey, and a series of expert workshops, we proposed an *a priori* model of ES success with 41 mutually exclusive measures. Unlike the original Delone and McLean model, the *a priori* model is simply a measurement model for assessing the multidimensional phenomenon of ES success using four separate dimensions of success (constructs): system quality, information quality, individual impact, and organizational impact. The model does not purport any causality among the dimensions. Rather, the dimensions are posited to be correlated and additive measures of the same multidimensional phenomenon—ES success.

EXPLORATORY PHASE: THE WEIGHTS SURVEY

The purpose of the weights survey was to validate the *a priori* model derived from the inventory survey. A survey instrument was designed to operationalize the 41 measures of the four constructs⁶. The draft survey instrument was pilot tested with a selected sample of staff of the Queensland Government Treasury Department. Feedback from the pilot round respondents resulted in minor modifications to survey items. The same 27 public sector organizations from the exploratory round were again surveyed. 310 valid responses were received and nine responses were not included in the analysis due to missing data or perceived frivolity.

Following the weights survey, the study model and related instrument items were tested for construct and criterion validity and reliability. The 41 items were included in an exploratory factor analysis. In order to attain a more interpretable and parsimonious factor solution, of the 15 System Quality items and 10 Information Quality items, 6 and 4 items were dropped respectively. All items loading as anticipated explaining 67 % of model variance, with all factors having Cronbach alphas greater than 0.9.

The survey instrument elicited criterion measures of overall success in response to each of two statements: (A) “Overall, the impact of SAP on the **agency** has been positive” and (B) “Overall, the impact of SAP on **me** has been positive.” The extent to which the success dimensions correlates with the criterion scores is evidence of their criterion validity⁷. All correlations showed strong correlations (all above 0.8) in at the .001 significance level.

CONFIRMATORY PHASE: THE CONFIRMATORY SURVEY

The purpose of the confirmatory survey is to validate the ES success model and the related instrument derived from the exploratory phase using confirmatory data analysis techniques. To gain a rigorous and a systematic standardised ES success instrument, the confirmatory analysis was supplemented with the standard validity and reliability tests. The factor solution of the *confirmatory survey* was identical to the analysis of the weights survey. This establishes the content validity of the instrument. The exploratory factor solution explained 74.3% variance of the model. All constructs illustrated high reliability with Cronbach Alpha above 0.90. Similar to the analysis of the weights survey, all constructs loaded on to a single higher order factor in the second order exploratory analysis.

Confirmatory factor analysis involves the specification and estimation of one or more putative models of factor structures, each of which proposes a set of latent variables to account for covariance among a set of observed variables (Bagozzi, 1980; Bollen, 1989; Joreskog and Sorbom 2001, Doll, Xia, Torkzadeh, 1994). Based on logic, theory and previous study results, four plausible alternative models structure factors, depicted in figure 2 are proposed. To establish model-data fit and evidence of factors, each model is assessed using the goodness of fit indicators. During this process, models should not be respecified. A model is then selected based on a number of fit indicators available in LISREL. The following section briefly describes the four alternative models derived in the study⁸.

⁴ Reasons for dropping the Shang and Seddon (2000) framework include overlaps between the constructs and measures; its strong emphasis on top managerial perspective (not a holistic view); and its somewhat narrow emphasis on organizational performance.

⁵ The ES success measurement model deviates from the Delone and McLean IS success model in the following ways: (1) Removal of the Delone and McLean ‘use’ construct; (2) Removal of ‘user satisfaction’ as a dimension of success; (3) Define a more expansive organizational impacts construct; (4) Introduce further ES-related measures, and (5) Remove measures that are inappropriate for this study.

⁶ The *a priori* survey instrument available upon request

⁷ This method of validation assumes the criterion items are valid (Kerlinger 1988)

⁸ The four alternative models are adapted from Doll et al. 1994

ALTERNATIVE MODELS

Model 1 is hypothesises four first order factors (constructs of ES success) and one second order factor (enterprise system success). Gable Sedera Chan (2003) pointed out the possibility of using second order exploratory factor analysis to illustrate additivity of the constructs and the validity of the ES success measurement model. Tanaka and Huba (1984) argue that it is possible to illustrate a second-order factor, if the first order factors are highly correlated.

The 2nd model illustrates a first-order factor solution with all constructs inter-correlated with each other. Gable Sedera and Chan (2003) expressed some evidence of high correlations between the constructs of ES success.

Model 3 hypothesizes one first-order factor, namely 'Enterprise Systems success', accounts for all the common variance among the all 27 items. Prior studies on performance evaluation (i.e. Balanced Scorecard - Kaplan and Norton 1992) suggest that all success measures be combined to yield an indicator of overall success.

Model 4 proposes that the measures of ES success form into four uncorrelated (orthogonal) first order factors. Gable Sedera Chan (2003) use varimax-orthogonal factor rotation. Thus, this model is deemed plausible.

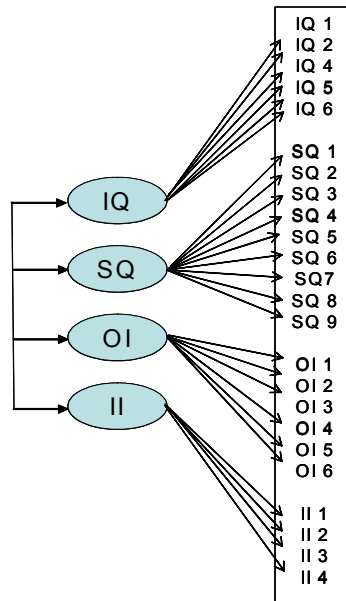
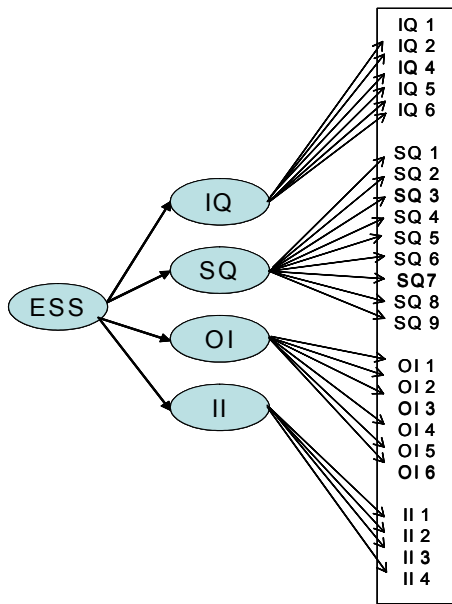
ASSESSING THE MODEL FIT

Many researchers have attracted to structural equation modelling due to its availability of global measures, which in practice often used as omnibus test of the model. Joreskog and Sorbom (2001) suggests that such assessments should be made (global fit indicators) before analysing the individual parameters. A variety of fit indicators are currently available to assess the model 'fit' with data. Tanaka (1993) identifies three types of model fit indicators: (1) absolute model fit, (2) comparative model fit and (3) parsimonious model fit⁹.

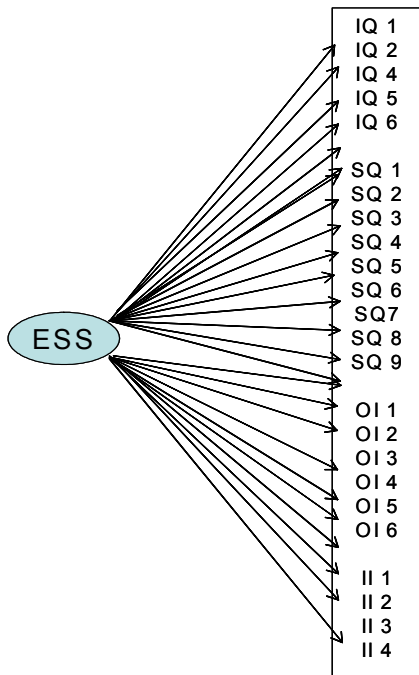
The fit indicators of the four alternative models are summarised in Table 2. Following observations are subsequently made about the four alternative models based on several fit indicators¹⁰.

⁹ See Kelloway 1998 for a summary of fit indicators

¹⁰ Models were not respecified and no validated items were dropped to attain higher fit with the data



Model 3: One first order factor



Model 4: Four first order factor (uncorrelated)

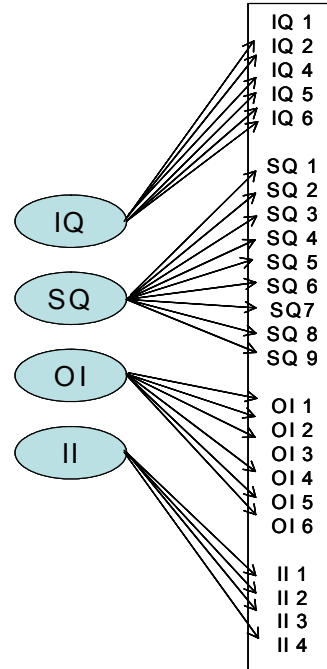


Figure 2: Alternative models of ES success instrument

			Reported Values			
	Abbreviation	Best Range	Model 1	Model 2	Model 3	Model 4
Absolute Fit Measures						
Root Mean Square	RMR	Close to 0	0.037	0.086	0.11	0.39
Standerized Root Mean Square	SRMR	< 0.05	0.067	0.068	0.11	0.39
Root Mean Squared error of approximation	RMSEA	<0.1	0.07	0.13	0.23	0.15
Goodness of Fit Index	GFI	>0.9	0.78	0.66	0.43	0.6
Adjusted Goodness of Fit Index	AGFI	>0.9	0.68	0.6	0.33	0.53
Chi Sqr / DF	X2/df	<5	2.28	3.23	6.66	4.18
Comparative Fit Measures						
Normed Fit Index	NFI	>0.9	0.94	0.93	0.85	0.9
NonNormed Fit Index	NNFI	>0.9	0.97	0.94	0.86	0.92
Incremental Fit Index	IFI	0 to 1	0.97	0.95	0.87	0.93
Parsimonious Fit Measures						
Parsimonious Normed Fit Index	PNFI	0 to 1	0.86	0.84	0.78	0.83
Parsimonious Goodness of Fit Index	PGFI	0 to 1	0.61	0.55	0.37	0.51

Table 2: LISREL model fit indicators

The Root Mean Square (RMR) of models 1 and 2 show reasonable fit with data. However, RMR is sensitive to the scale of measurement and therefore it is difficult to establish what a 'low' value is. Standardized RMR, which eliminates this problem of RMR, recommends values less than 0.05 as indicating of good fit to the data. Based on the above cut-off of SRMR, models 1 and 2 show a reasonably good fit with data. Root Mean Squared Error of Approximation (RMSEA) developed by Steiger (1990) provides similar information to SRMR. Steiger (1990) suggests that values below indicating good fit to the data, values below 0.05 indicating very good fit and values below 0.01 indicating outstanding fit to the data. However, he notes that this is very rarely achieved. Only model 1 shows good fit based on this index. Goodness of Fit (GFI) is another fit index of model 1 displays reasonable fit with the data. Although values over 0.9 are generally considered as good fit for GFI, the GFI should be treated with caution and changes in different samples (Kelloway, 1998). The Adjusted Goodness of Fit Index (AGFI) theoretically ranges from 0 to 1, with values over 0.9 considered as good fit with data. However, similar to the GFI, values over 0.9 are rarely achieved. Furthermore, in second order confirmatory factor solutions GFI and AGFI values are slightly suppressed. None of the models display good fit with data for this index. Medsker, Williams and Holaham (1994) introduced the notion of chi-square and degree of freedom as an index, treating ratios between 2 to 5 indicating good fit. Model 1 and model 2 display good fit with data according to the Chi-square/df classification. From the comparative fit measures, the Normed Fit Index (NFI) and the Non Normed Fit Index (NNFI) is considered first. The two indicators of table 2 refer to parsimonious fit of the data to models. The Parsimonious Normed Fit Index (PNFI) and the Parsimonious Goodness of Fit Index (PGFI) range from 0 to 1, with higher values indicating good fit. However, neither PNFI nor PGFI are likely to reach the accepted 0.90 level used for most of the other indicators. Instead, the indicators are best used for comparing alternative models. Model 1 display higher values in both PNFI and PGFI. Analysing the results thus far, it is clear that Model 1 – 2nd order factor model – provides better fit to the data than any other model. Model 2 provides some goodness of fit and provides substantial improvement over other two models in data fit. Finally, in empirical comparison of Model 1 and Model 2 we establish the target coefficient to illustrate the existence of the second order overarching factor (Doll et al., 1994). Using model 2 as the target model, the target coefficient is established¹¹. The target coefficient of 0.70 is reported illustrating that 70% of the variance in model 2 (first order factors) is explained by the higher order factor in model 1.

Considering all evidence of the LISREL confirmatory analysis, the exploratory analysis completed using SPSS, statistical results of both phases of the research cycle and using theory and logic it is established that model 1 explains the ES success phenomenon better than any other alternative models.

CONCLUSION

This paper has presented a validated model and instrument for measuring enterprise system success by completing the full research cycle of Mackenzie and House (1979). The constructs and the measures of the study provide the most complete and comprehensive success measurement study to-date and it is the first such validated instrument in the field of Information Systems (or any contemporary IS¹²) published in the IS academic literature.

¹¹ The target coefficient is the ratio of the chi-square of model 2 to the chi-square of model 1.

¹² See discussion in Gable Sedera Chan 2003

The study conducted three separate surveys (two for the exploratory phase and one for the confirmatory phase) analysing 600 respondents in total. Given past IS success studies have lacked theoretical grounding, the selection of model constructs in this study was grounded in the inventory (model building) survey aimed at confirming the relevance and completeness of the most widely cited IS success model. The constructs and measures identified in the inventory survey were then empirically tested in the weights survey (model testing), completing the exploratory phase of the research cycle. The refined items of the exploratory phase were tested with four alternative models in separate environment with a different ES application to the exploratory round. Confirmatory factor analysis was employed in this analysis and was supplemented by traditional exploratory analysis. The final analysis suggests the existence of four distinct and individually important dimensions of success that the authors believe are applicable to *any* IS evaluation. The constructs are positively associated and when combined yield a single valid measure of overall success.

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